Water Quality Monitoring for Watershed Protection Plan, Bogue Falaya and Abita Watersheds

CFMS Contract No.: <u>691076</u>

FINAL REPORT

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LAKE PONTCHARTRAIN BASIN FOUNDATION

SAVE OUR COAST SAVE OUR LAKE

CFMS Contract No.: 691076
Cooperator: Lake Pontchartrain Basin Foundation
Project Title: "Water Quality Monitoring for Watershed Protection Plan, Bogue Falaya and Abita Watersheds"

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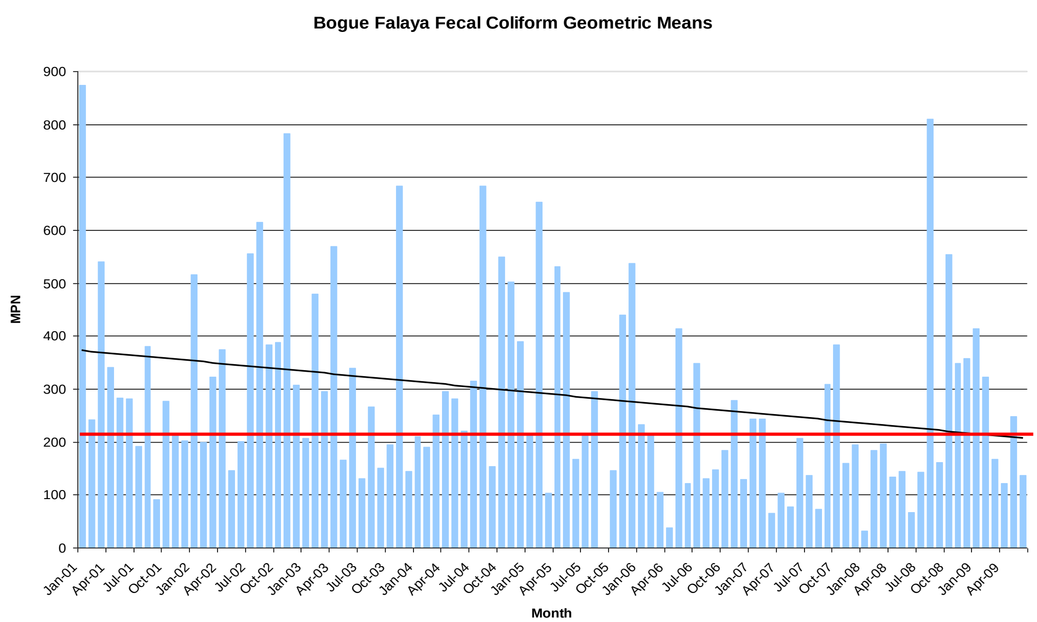
1.0 INTRODUCTION

Program Background: The Lake Pontchartrain Basin Foundation (LPBF), in association with the Louisiana Department of Health and Hospitals (DHH), began performing intensive water quality monitoring around the Basin in 2001. Data analysis revealed sites north of the Lake to have significantly higher fecal coliform counts than sites south of the Lake. In 2002, LPBF began to investigate the sources of fecal pollution contributing to the high counts observed on north shore waterways, breaking down the task by sub-watershed. The LPBF's "Sub-Basin Pollution Source Tracking Program" utilizes water quality analysis and geographic information systems (GIS) mapping to locate potential sources of pollution then provides on-the-ground assistance to correct the sources. To date, the Bogue Falaya, Tchefuncte, Tangipahoa, Natalbany, and Tickfaw watersheds have undergone this program. In the Bogue Falaya, the program resulted in dramatic decreases in fecal coliform levels (Figure 1) and the Bogue Falaya, Tchefuncte and Tangipahoa Rivers were removed from Impaired Water bodies List for fecal coliform bacteria in 2008.

Figure 1. Fecal Coliform Geometric Means 2001 - 2009



Bogue Falaya Watershed Implementation Plan (WIP): Building on a decade of pollution source tracking, the LPBF began working with the Louisiana Department of Environmental Quality (LDEQ) in the writing and implementation of WIPs for watersheds within the Pontchartrain

Basin in 2009. LPBF has completed writing and is currently implementing the WIP for the Bogue Falaya and Abita River Watersheds (Bourgeois-Calvin and Core, 2012). A significant task of the plan is the documentation of historic, current, and future water quality within the watersheds. LPBF monitored these watersheds in the past and wanted to monitor them as part of the WIP. In addition, LPBF wanted to add new parameters, a suite of nutrients, to the analyses. The intention was to use the water monitoring to document current conditions, identify pollution sources or reaches where water quality problems are prevalent, and document future (improving) water quality as a result of the plan.

Finally, the Lower Tchefuncte River Dissolved Oxygen Total Maximum Daily Load (TMDL) was released in August 2011. It states the following as sources: "Numerous individual commercial package plants and individual residential treatment units discharging directly or indirectly within the watershed are suspected of having a major impact on the Lower Tchefuncte River. This includes facilities in subsegment 040801 (Bogue Falaya River) and 040804." and calls for a 67% reduction in oxygen-demanding substances in the lower Tchefuncte River (Figure 2).

Figure 2. Lower Tchefuncte River Oxygen-Demanding Load Reductions from TMDL)

Table 7. Subsegment 040802 Total Maximum Daily Load (Sum of UCBOD[1], UNBOD, and SOD) for a 5.0 mg/L dissolved oxygen standard

ALLOCATIONS	SUMMER		WINTER	
	% Reduction Required	(MAY-OCT) (lbs/day)	% Reduction Required	(NOV-APR) (lbs/day)
Point Source Wasteload Allocation (WLA)	Tchefuncte River 67% above Hwy 22, 85% for Ponchitolawa Creek, 85% for Bayou Tete L'Ours above Hwy 190, 76% for Bayou Tete L'Ours below Hwy 190, and 76% for Bayou DeZaire	682	Tchefuncte River 67% above Hwy 22, 85% for Ponchitolawa Creek, 85% for Bayou Tete L'Ours above Hwy 190, 76% for Bayou Tete L'Ours below Hwy 190, and 76% for Bayou DeZaire	682
Point Source Reserve MOS (20%)		171		171
St. Tammany Parish MS4 WLA (Nonpoint Loads)	Tchefuncte River 67% above Hwy 22, 85% for Ponchitolawa Creek, 85% for Bayou Tete L'Ours above Hwy 190, 76% for Bayou Tete L'Ours below Hwy 190, and 76% for Bayou DeZaire	2,552	Tchefuncte River 67% above Hwy 22, 85% for Ponchitolawa Creek, 85% for Bayou Tete L'Ours above Hwy 190, 76% for Bayou Tete L'Ours below Hwy 190, and 76% for Bayou DeZaire	1,963
St. Tammany Parish MS4 MOS (Nonpoint Source Reserve MOS) (20%)		642		491
City of Mandeville MS4 WLA (Nonpoint Loads)	Tchefuncte River 67% above Hwy 22, 85% for Ponchitolawa Creek, 85% for Bayou Tete L'Ours above Hwy 190, 76% for Bayou Tete L'Ours below Hwy 190, and 76% for Bayou DeZaire	169	Tchefuncte River 67% above Hwy 22, 85% for Ponchitolawa Creek, 85% for Bayou Tete L'Ours above Hwy 190, 76% for Bayou Tete L'Ours below Hwy 190, and 76% for Bayou DeZaire	130
City of Mandeville MS4 MOS (Nonpoint Source Reserve MOS) (20%)		43		33
Nonpoint Loads	Tchefuncte River 67% above Hwy 22, 85% for Ponchitolawa Creek, 85% for Bayou Tete L'Ours above Hwy 190, 76% for Bayou Tete L'Ours below Hwy 190, and 76% for Bayou DeZaire	6,365	Tchefuncte River 67% above Hwy 22, 85% for Ponchitolawa Creek, 85% for Bayou Tete L'Ours above Hwy 190, 76% for Bayou Tete L'Ours below Hwy 190, and 76% for Bayou DeZaire	4,895
Nonpoint Source Reserve MOS (20%)		1,601		1,224
TMDL		12,225		9,588

***Note1: UCBOD as stated in this allocation is Ultimate CBOD.
UCBOD to $CBOD_5$ ratio = 2.3 for all treatment levels
Permit allocations are generally based on $CBOD_5$***

2.0 TASKS

The Scope of Services for this grant listed the following tasks for completion.

A) Quality Assurance Project Plan (QAPP) Development Requirement: All work funded by this contract involving the acquisition of environmental data generated from direct measurement activities, collected from other sources, or compiled from computerized data bases and information systems shall be implemented in accordance with an approved QAPP. The QAPP will be developed using a systematic planning process. It will document a concise and complete plan for the environmental data operation and its quality objectives and will identify key project personnel. Any costs for data generation or environmental measurements incurred prior to approval of the original QAPP will be ineligible for reimbursement under this contract.

   Develop draft QAPP for approval: The QAPP will describe the project management and the collection, analysis, evaluation, and reporting of all data collected during the project. The document will be developed according to the Environmental Protection Agency (EPA) requirements for QAPPs (EPA QA/R-5) and guidance for QAPPs (EPA QA/G-5) and will address each element of the project.

   The contractor is responsible for maintaining an electronic version of the QAPP in Microsoft (MS) Word.

   None of the environmental work addressed by the QAPP shall be started until the QAPP has been approved and distributed to project personnel.

   The contractor shall ensure that the QAPP is implemented and that all personnel involved in the work have direct access to and understanding of the QAPP and all other necessary planning, implementation, and assessment documents. These personnel should understand the requirements prior to the start of data generation activities.

B) Utilize LPBF (EPA-approved) equipment to monitor the parameters of water temperature, dissolved oxygen, specific conductance, and turbidity in the Bogue Falaya and Abita River and their tributaries.

C) Concurrent to the water quality sampling in B, collect one grab sample for fecal coliform and *E. coli* bacteria. Utilize the Louisiana Environmental Laboratory Accreditation Program (LELAP) approved Southeastern Louisiana University (SLU) Microbiology Laboratory for the analysis of fecal coliform and *E.coli* bacteria.

D) Concurrent to the water quality sampling in A, collect one grab sample for nutrient analysis. Utilize the LELAP-approved SLU Microbiology Laboratory for the analysis of ammonium/ammonia (NH_4/NH_3), nitrate-nitrite-nitrogen (NO_{2-}-NO_{3-}-N), total nitrogen (TN), total organic carbon (TOC), total inorganic carbon (TOC), total phosphate (TPO_4), and alkalinity.

E) Perform the above monitoring regime (listed in B, C and D) at 10 sites located within the Bogue Falaya and Abita watersheds on a bi-weekly basis (25 times per year) throughout the course of the WIP writing and implementation.

F) Provide data generated through this project to the Department in format suitable for downloading into the Department's database.

G) Prepare a final report and summary of the sampling activities and results at the end of the year. This report will include a discussion of the findings related to the sampling results.

3.0 METHODOLOGY

Study Site: The Bogue Falaya is a tributary of the Tchefuncte River that flows through St. Tammany Parish. The Bogue Falaya Watershed is 135 mi^2 and has 4 HUC 12 sub-watersheds. The Abita River is a tributary of the Bogue Falaya. The Abita River Watershed is 63 mi^2 and has 2 HUC 12 sub-watersheds (Figure 3).

Sample Sites: The LPBF selected 10 sample sites (BFAB1-BFAB10) along the Bogue Falaya and Abita Rivers and their major tributaries (Figure 3). Sites BFAB1-6 were located within the Bogue Falaya River watershed and sites BFAB7-10 in the Abita River watershed (Figure 3). Coordinates for each site were obtained via Google Earth and then ground-truthed using the GARMIN eTrex Legend HCx handheld. Coordinates (decimal degrees) were used to map the sample site point layer in ArcMap 10. Water quality data were collected (481 total samples, roughly 49 samples from each site) from September 2010 through July 2012.

Bogue Falaya / Abita Sample Sites:

NAME	SITE	PLACE	LAT	LON
BF @ Menetre Boat Launch	BFAB6	Covington	30.455971	-90.105142
BF @ Hosmer Mill Rd	BFAB4	Covington	30.519813	-90.102009
BF @ Million Dollar Rd	BFAB3	Covington	30.556440	-90.146128
Simalusa @ Fredrick Church Rd.	BFAB2	Folsom	30.590473	-90.100742
BF @ Hwy 40 (Blackwell Cem Rd)	BFAB1	Folsom	30.628419	-90.171129
Little BF @ Holly Dr.	BFAB5	Covington	30.491424	-90.075216

NAME		PLACE	LAT	LON
English Br. @ N. Hollyoak Dr.	BFAB8	Abita	30.485503	-90.008490
Abita @ Abita Tourist Park Bridge	BFAB9	Abita	30.480527	-90.041026
Abita @ Keen Rd Bridge	BFAB7	Abita	30.503098	-89.991312
Abita @ Hwy 90 Bridge	BFAB10	Covington	30.460184	-90.082351

Water Monitoring Methods: The sites were monitored bi-weekly (by car). Water temperature, dissolved oxygen, specific conductance, pH, and turbidity were monitored *in situ*. One 120 ml grab sample for fecal coliform and *E. coli* bacteria was collected at each site on each sampling date. Concurrently, one grab sample of 1 liter volume was collected for nutrient analysis. Nutrients analyzed include NH_4/NH_3, NO_{2-}-NO_{3-}-N, total nitrogen, total organic carbon, total inorganic carbon, total phosphate, and alkalinity. The LELAP-approved Southeastern Louisiana University Microbiology Laboratory was utilized for all bacteriological and nutrient analyses. Parameters and methods are detailed in Appendix B.

Equipment: LPBF utilized a YSI 85 Water Temperature, Dissolved Oxygen, Specific Conductance, and Salinity meter, a YSI 60 pH meter, and a Hach 2100P Portable Turbidimeter to collect *in situ* parameters. Equipment was calibrated daily as per instruction manuals. Equipment had semi-annual calibration in January and July of each year. Regular maintenance was performed on the equipment as needed. A new YSI 85 meter with a longer cord was purchased by LPBF midway through the monitoring.

QAPP: The QAPP that covered the monitoring activities in this project was entitled "Sub-Basin Water Quality Analysis and Pollution Source Tracking (Tangipahoa Parish: Tangipahoa and Tickfaw Watersheds AND St. Tammany Parish: Bogue Falaya and Abita Watersheds)"- EPA Q-Track #'s 11-036 (2010) and 12-050 (2011 update).

Data Analysis: For data analysis, two statistical methods were used to find 1) correlations among the water quality parameters, and 2) variations among sample sites to reveal sources of pollution within the Bogue Falaya River and Abita River watersheds.

- **Interval or ratio level of measurement: principal component analysis (PCA)**

http://www.utdallas.edu/~herve/Abdi-MultivariateAnalysis-pretty.pdf

The goal of PCA is to decompose a data table with correlated measurements into a new set of uncorrelated (i.e., orthogonal) variables. These variables are called, depending upon the context, principal components, factors, eigenvectors, singular vectors, or loadings. Each unit is also assigned a set of scores which correspond to its projection on the components.

The results of the analysis are often presented with graphs plotting the projections of the units onto the components, and the loadings of the variables (the so-called "circle of correlations"). The importance of each component is expressed by the variance (i.e., eigenvalue) of its projections or by the proportion of the variance explained. In this context, PCA is interpreted as an orthogonal decomposition of the variance (also called inertia) of a data table.

- **Kruskal–Wallis one-way analysis of variance**

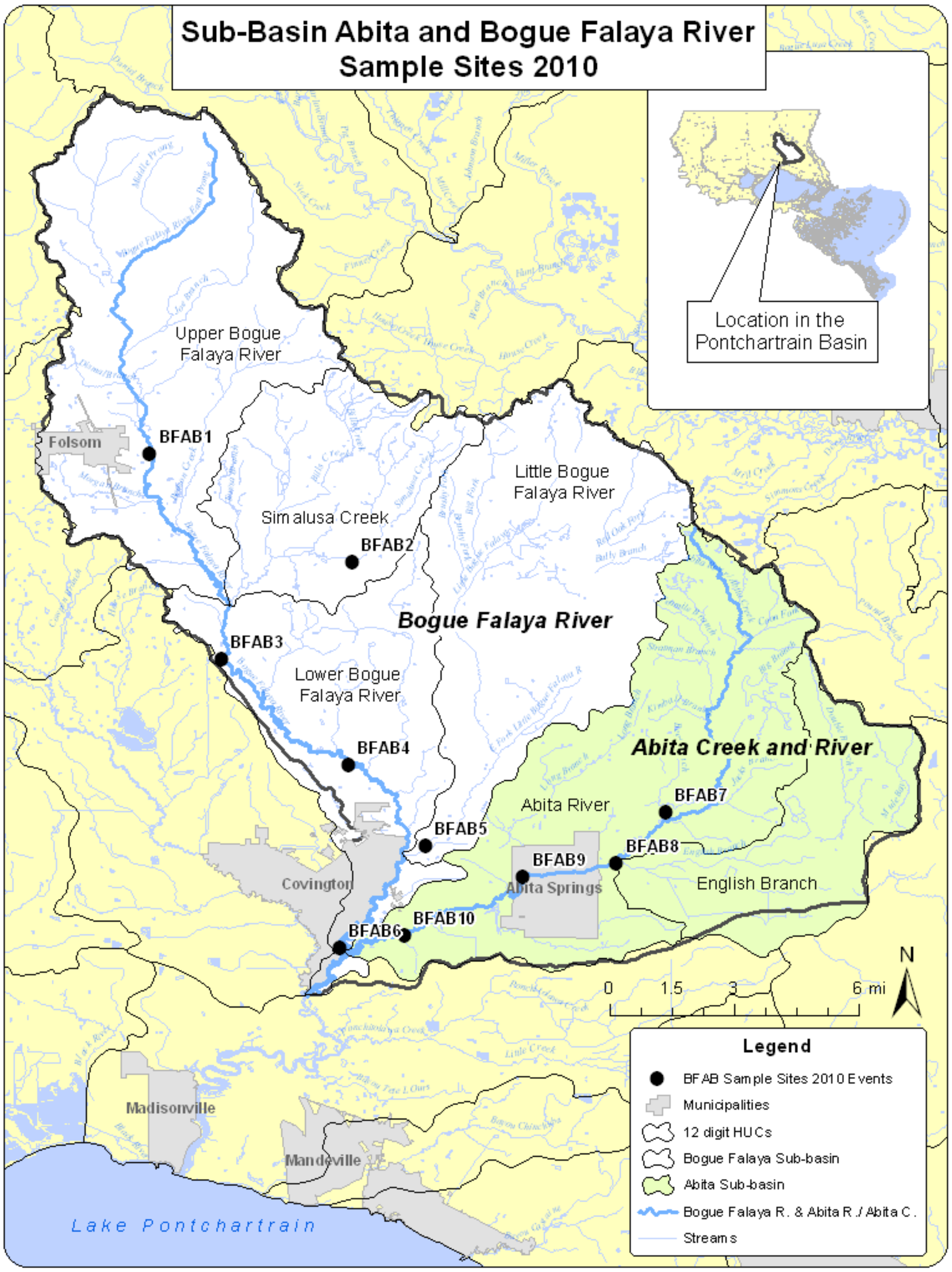
http://en.wikipedia.org/wiki/Kruskal%E2%80%93Wallis_one-way_analysis_of_variance

In statistics, the **Kruskal–Wallis one-way analysis of variance** by ranks … is a non-parametric method for testing whether samples originate from the same distribution. It is used for comparing more than two samples that are independent, or not related. The parametric equivalence of the Kruskal-Wallis test is the one-way analysis of variance (ANOVA). The factual null hypothesis is that the populations from which the samples originate have the same median. When the Kruskal-

Wallis test leads to significant results, then at least one of the samples is different from the other samples. The test does not identify where the differences occur or how many differences actually occur.

Since it is a non-parametric method, the Kruskal–Wallis test does not assume a normal distribution, unlike the analogous one-way analysis of variance. However, the test does assume an identically shaped and scaled distribution for each group, except for any difference in medians.

Figure 3. Bogue Falaya and Abita Sample Sites



4.0 RESULTS

Within the Bogue Falaya and Abita River watersheds, water quality samples were taken bi-weekly for 20 months at ten sample site locations (See Figure 3). Over that period, 49 samples were collected at each of the ten sample sites. Sample sites BFAB 1-6 were located in the Bogue Falaya River watershed, and sites BFAB7-10 fell within the Abita River watershed.

Comparison Between Sites: Water temperature was within normal and expected ranges for all sites (Figure 4). Dissolved oxygen was generally above the state standard of 5 mg/l in the Bogue Falaya watershed, the exception being Simalusa Creek (BFAB2), which experienced periods of little to no flow. Oxygen levels dipped slightly into sights BFAB5 and BFAB 6. These sites were in the downstream area of the watershed (near the confluence with the Tchefuncte River) and experienced tidal influence. The sites were also located in the most urban area of the watershed. In contrast, sites within the Abita Watershed (Sites BFAB7-10) showed systemically lower dissolved oxygen levels, with some median values dipping below the state standard (Figure 5).

Figure 4. Temperature By Site

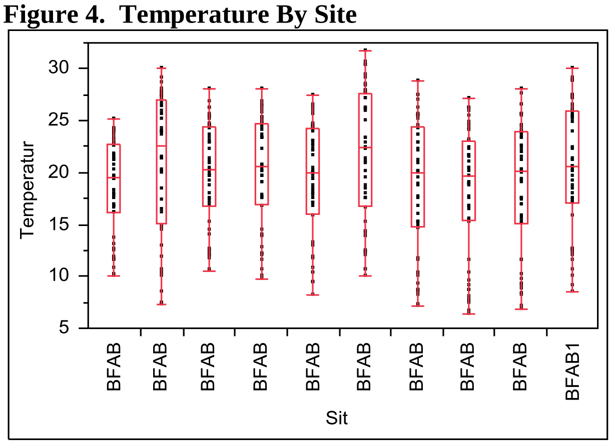
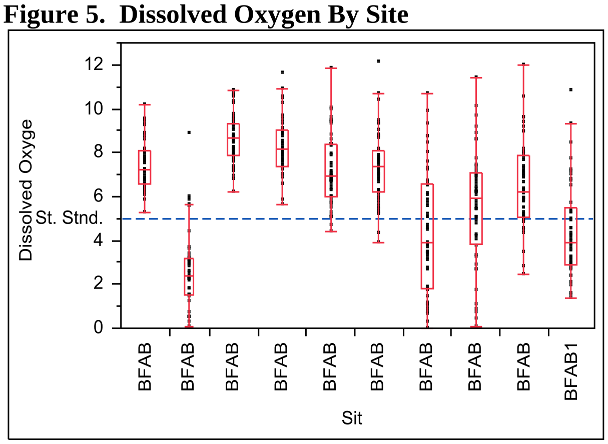


Figure 5. Dissolved Oxygen By Site



pH was within normal and expected range for all sites (Figure 6) and turbidity was below the state standard of 50 NTU's for all sites but Abita sites were generally higher (Figure 7).

Figure 6. pH By Site

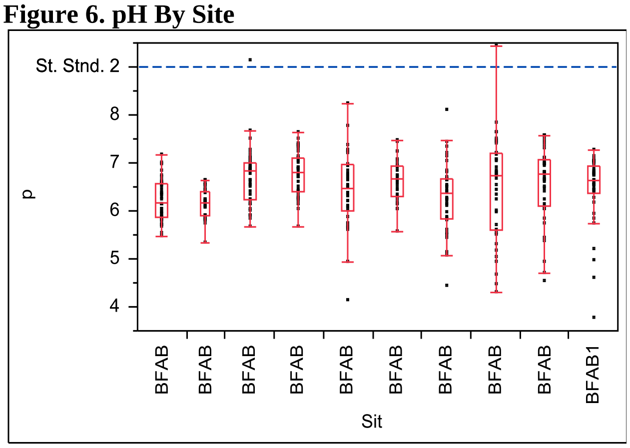
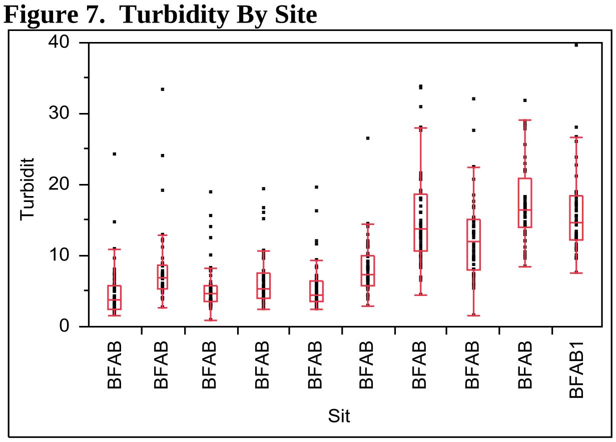


Figure 7. Turbidity By Site



In addition to turbidity, several other parameters showed either greater values or increasing values in the Abita Watershed. Alkalinity (Figure 8) and total inorganic carbon (TIC) (Figure 9) showed increasing values as the Abita River flowed downstream. As TIC is used in the alkalinity calculation, a correlation in values is expected. Total organic carbon (Figure 10) and ammonia-ammonium- nitrogen (Figure 11) showed overall greater values in the Abita Watershed. Paired with the low oxygen levels seen in the Abita, it could be that there was anaerobic break down of organic matter (measured by TOC) which could lead to higher ammonia/ammonium levels in the river.

Figure 8. Alkalinity By Site

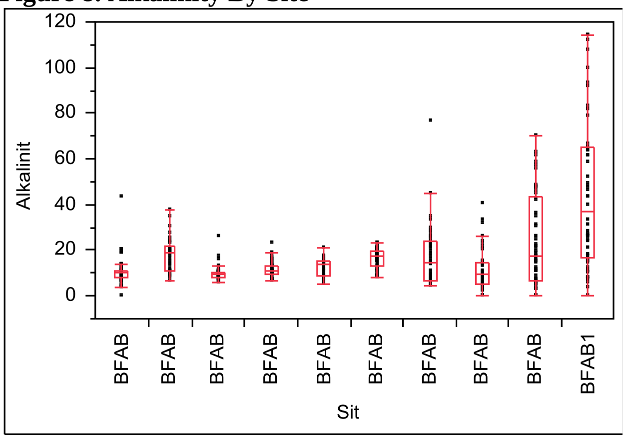


Figure 9. TIC-C By Site

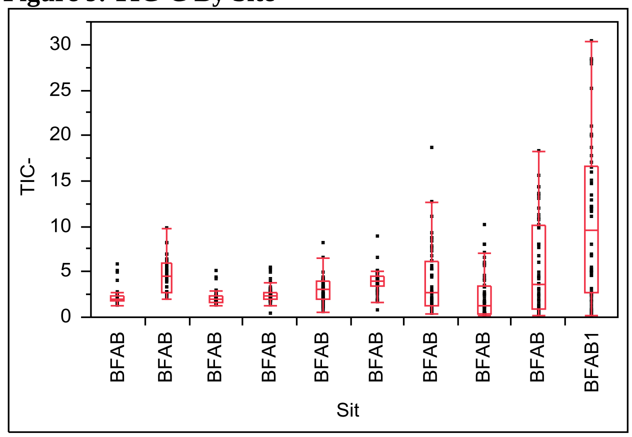


Figure 10. TOC-C By Site

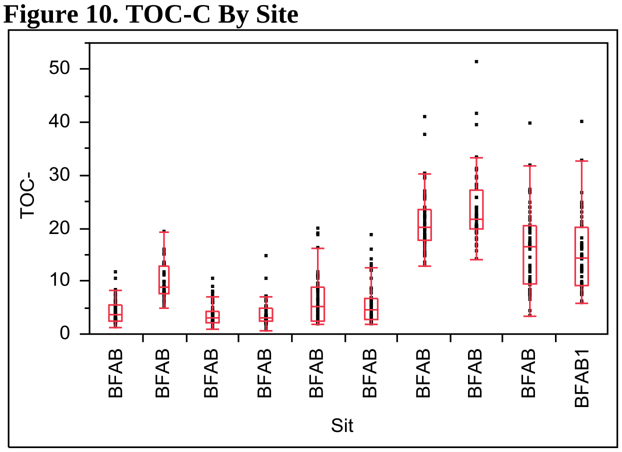
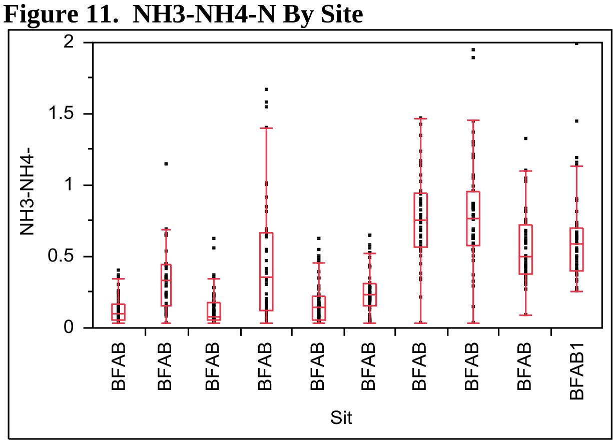


Figure 11. NH3-NH4-N By Site



A few parameters showed severe spikes at the most downstream Abita River site- BFAB10. Specific conductance (Figure 12) along with nitrogen and phosphorus species analyzed (Figures 13-15) showed significantly greater concentrations at the most downstream site in the Abita River. These values far exceed anything else seen in both the Bogue Falaya and Abita Rivers and indicate a significant contributing source or sources occurring between sites BFAB9 in the Town of Abita Springs and Site BFAB10. The potential contributing sources were further investigated by LPBF and the SLU Microbiology lab (shown in discussion below).

Figure 12. Specific Cond By Site

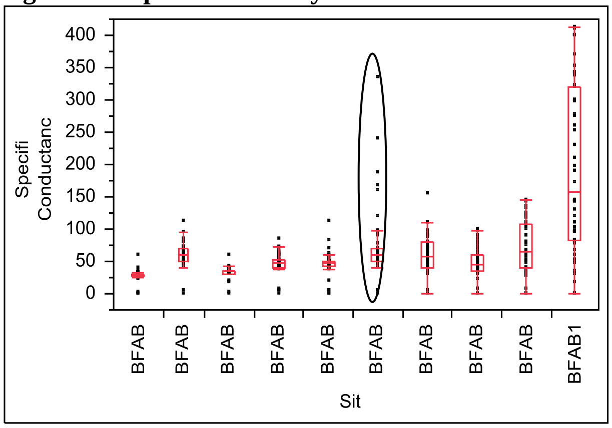


Figure 13. Phosphate-P By Site

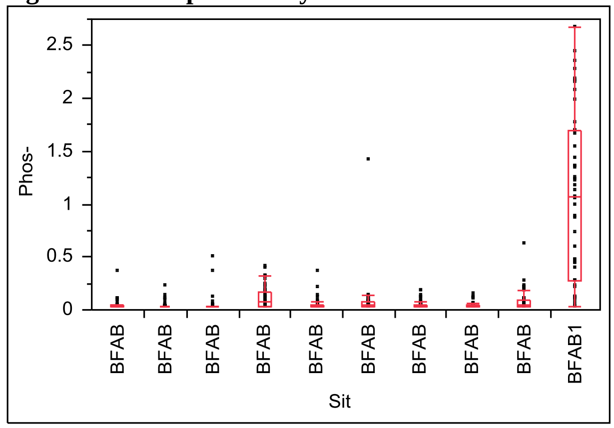


Figure 14. NO3-NO2-N By Site

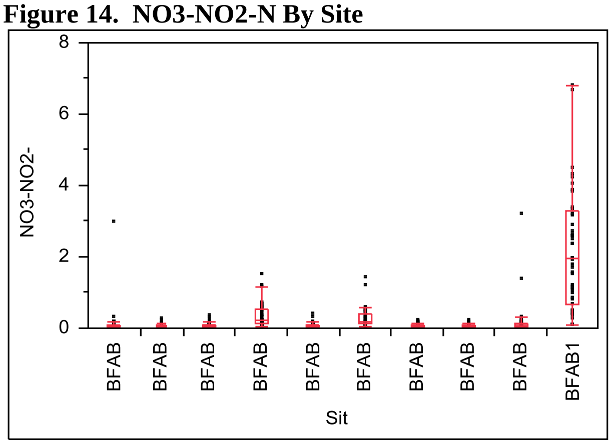
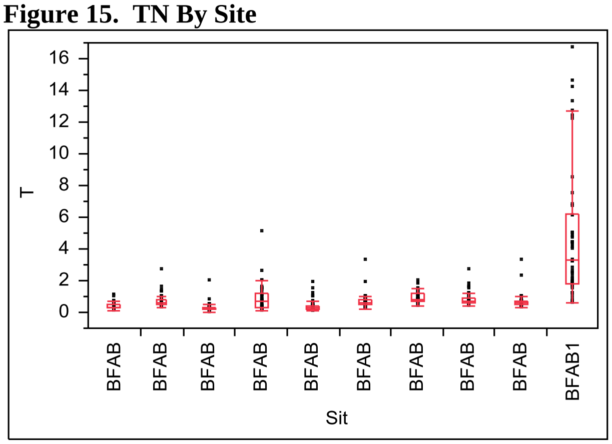


Figure 15. TN By Site



Fecal coliform and *E.coli* were significantly greater at Site BFAB9, the site in the Town of Abita Springs (Figures 16 & 17). This was the only site with at least 25% of samples above the state fecal coliform single sample standard of 400 MPN/ 100 ml water. This indicates a source or sources between BFAB7 and BFAB9 (as BFAB 8 is on a tributary). Site BFAB5 is the greatest for Bogue Falaya. A potential explanation as to why these sites are greatest in fecal coliform is given in the discussion below.

Figure 16. Fec Col By Site

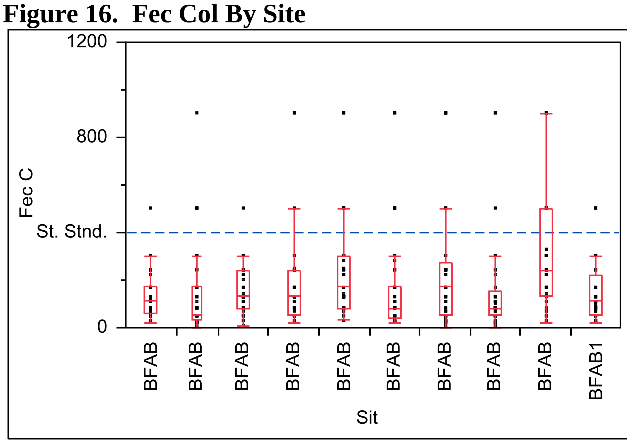
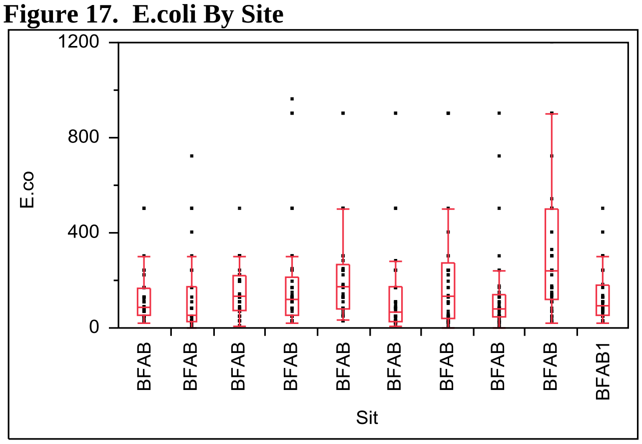
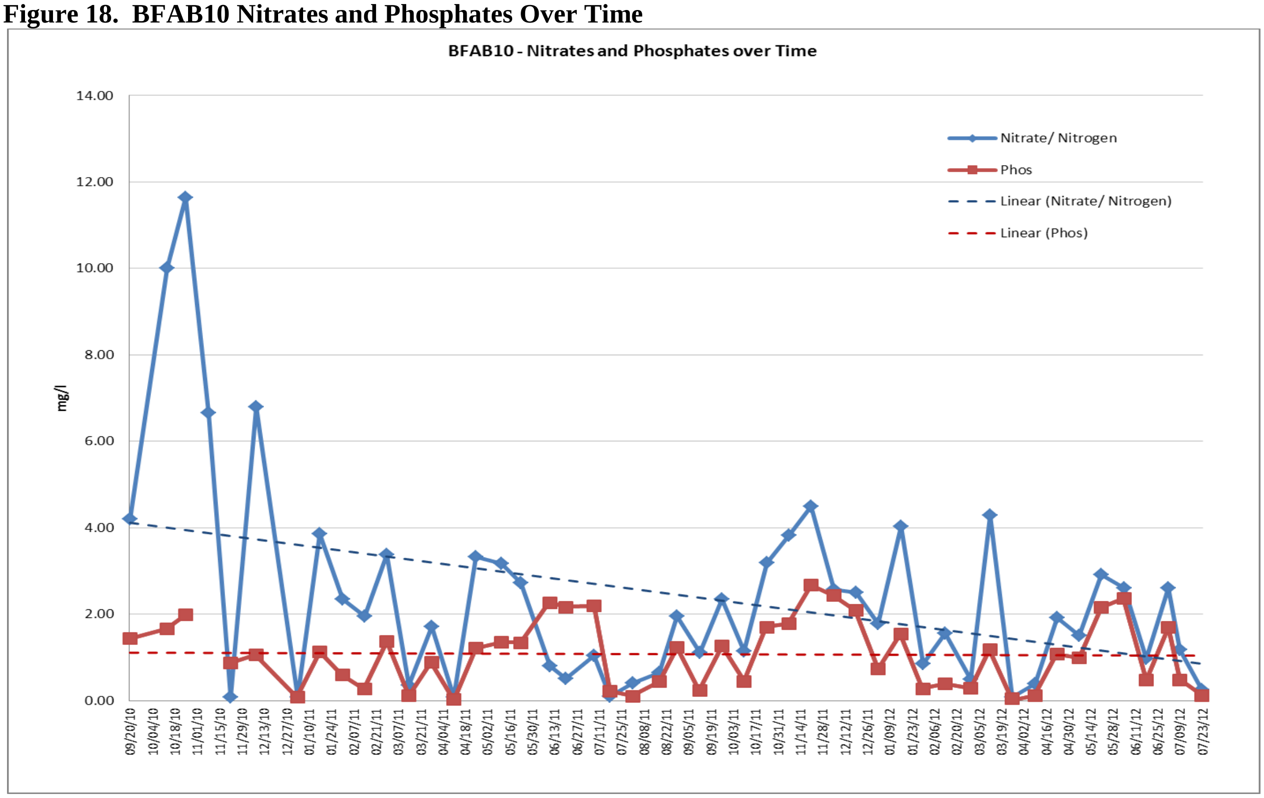


Figure 17. E.coli By Site



Trends Over Time: For the sites with high nutrient and fecal coliform levels, trends over time were analyzed. For site BFAB10, the NO_3-NO_2-N and Phos-P were plotted over time to assess chronological trends and overall pattern (Figure 18). The nitrate-nitrite-nitrogen (shown by blue data line) displayed the greatest values early in the sampling period then declined to under 4 mg/l for the remainder of the sampling period. This led to an overall linear decline (blue dashed line) with a beginning average of around 4 mg/l and an ending average of around 1 mg/l. This decline could potentially be due to the removal of a wastewater source (discussed in discussion below). The phosphates (red data line) showed a more consistent linear trend over time (red dashed line) with values ranging around 1 mg/l throughout the study. Phosphate could be more consistent as they can be stored in and released from sediments over time.

Figure 18. BFAB10 Nitrates and Phosphates Over Time



Fecal coliform was assessed chronologically for Site BFAB9, the site in the Abita watershed with the greatest fecal coliform levels (Figure 19). When a moving average (dotted line- accounting for 5 samples per average point) was used on the data, variation over time can be seen; however this variation does not correspond to seasonal patterns. The greatest spikes did, however, correspond to rain events equaling over 1 inch. When the linear trend was applied to the data (black solid line) the trend increased slightly throughout the course of the study, beginning below the state standard of 400 MPN/100 ml (red dashed line) and ending above.

When fecal coliform data from BFAB5 on the Bogue Falaya River was subjected to the same treatment, similar patterns were seen (Figure 20). BFAB5 also exhibited a variable moving average related to rain events and also showed a rising linear trend. As the Bogue Falaya was removed from the Impaired Waterbodies List for fecal coliform in 2008, it would be prudent to continue to observe this waterway to ensure that the fecal coliform does not continue to rise.

Figure 19. Chronological fecal coliform, including moving average and linear trend, on BFAB9

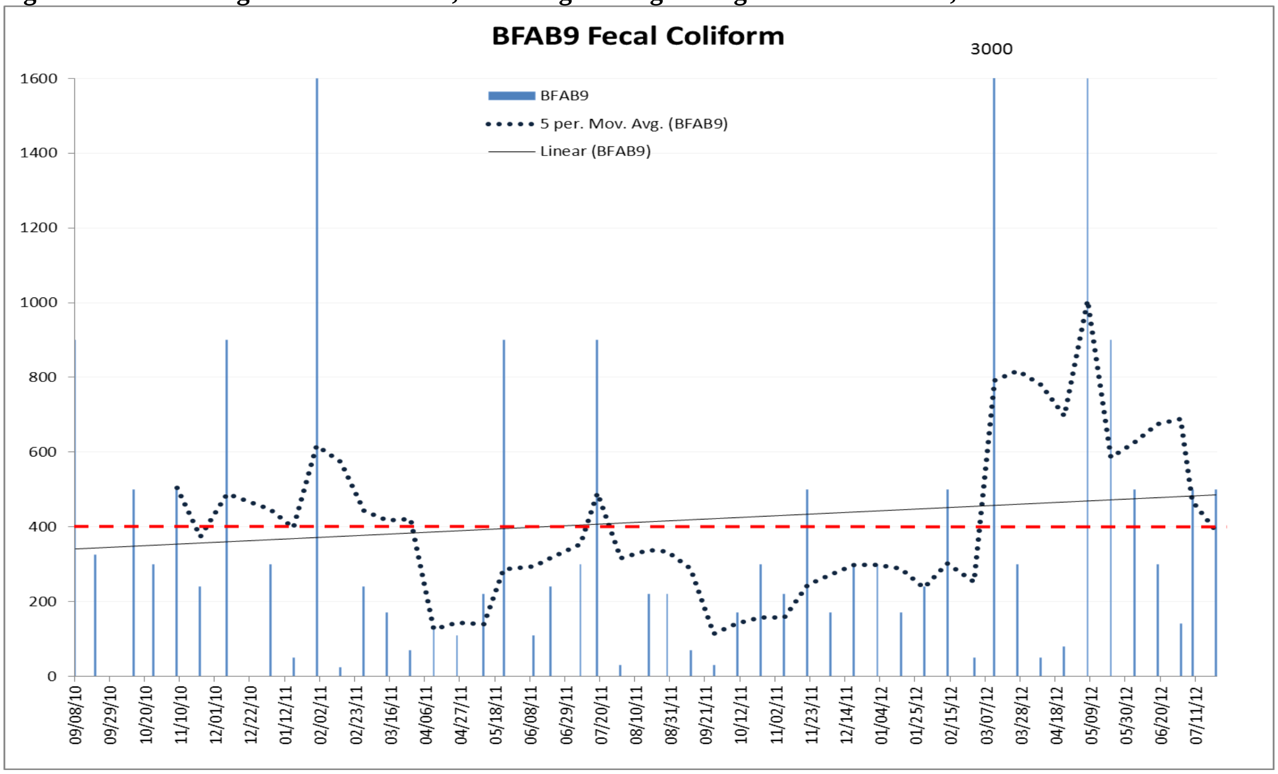
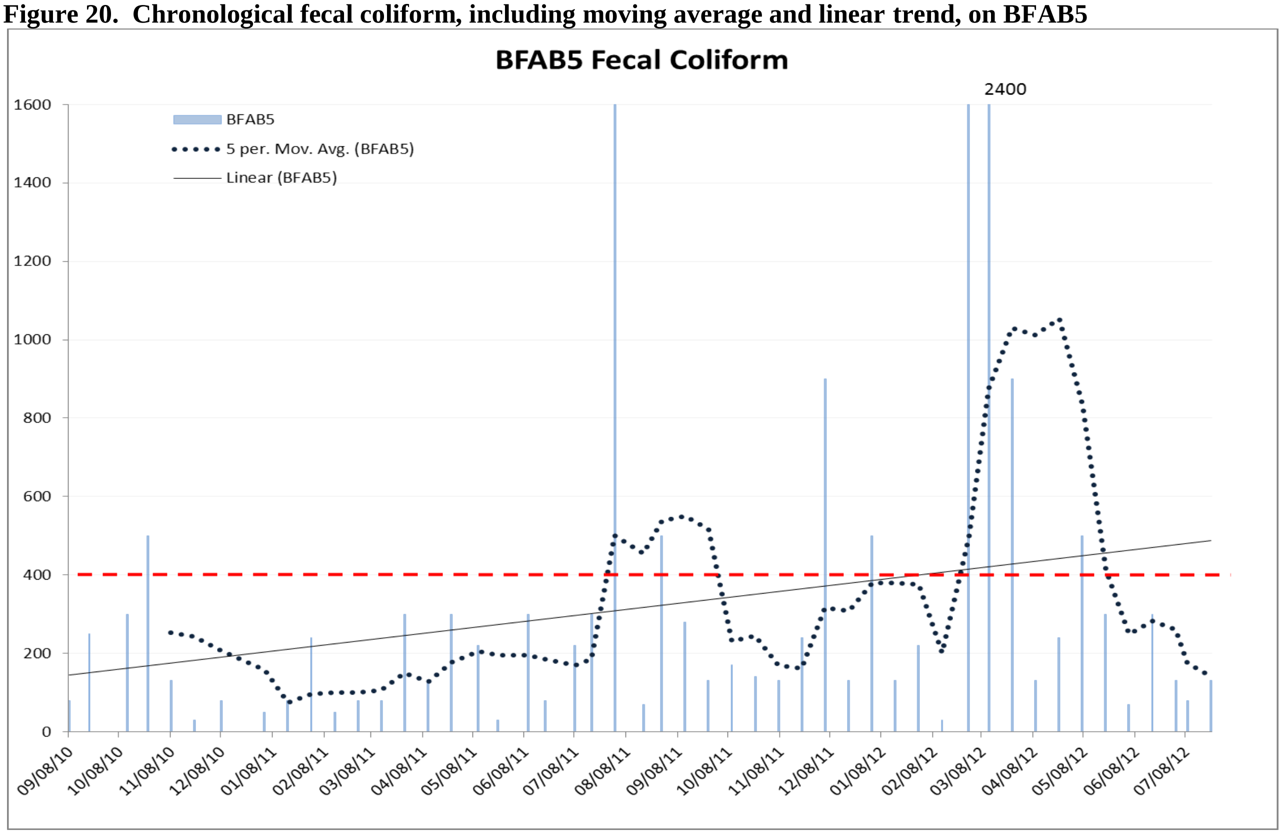


Figure 20. Chronological fecal coliform, including moving average and linear trend, on BFAB5



Principle Component Analysis: The Principal Components Analysis (PCA) reduces the dimensionality of a large dataset by transforming variables (Alkalinity, pH, IC, etc..) into a new dataset with a reduced set of factors that are related linearly to the original variables. This allows complex datasets to be more readily assessed. In relation to surface water quality, PCA can help characterize different sources of contamination by examining differences in factor scores from up river to downstream sites. Factor Loading bar graphs visualize the relative importance of individual variables to a given factor.

The factor loading charts below analyzed the large data set and produced four sets of variables with relation to each other for all sites monitored. Figure 21 shows that the fecal coliform and *E.coli* are closely related to each other but not to other parameters. Figure 22 shows that NO_3-NO_2-N, Phosphate, and TN are closely related- this pattern was seen particularly in BFAB10. Figure 23 shows that alkalinity, spec. conduct., and inorganic carbon are all positively correlated to each other and negatively correlated to dissolved oxygen. This relationship is particularly seen in the Abita River. Figure 24 shows that total organic carbon and turbidity are positively correlated with each other and negatively with dissolved oxygen and pH. This represents a preliminary analysis. LPBF and the SLU lab are further exploring these relationships.

Figure 21. Factor Loading 1

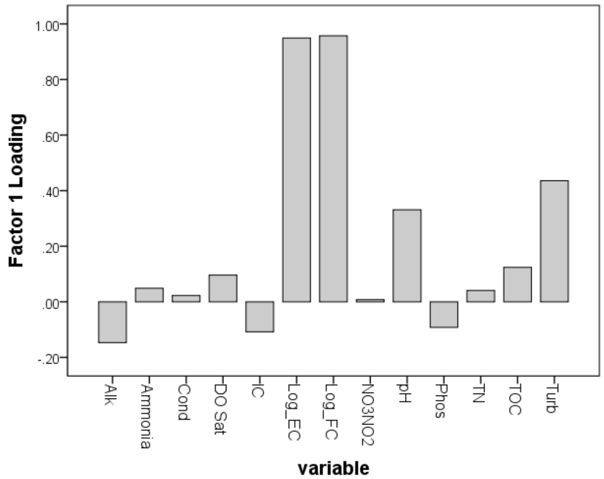


Figure 23. Factor Loading 3

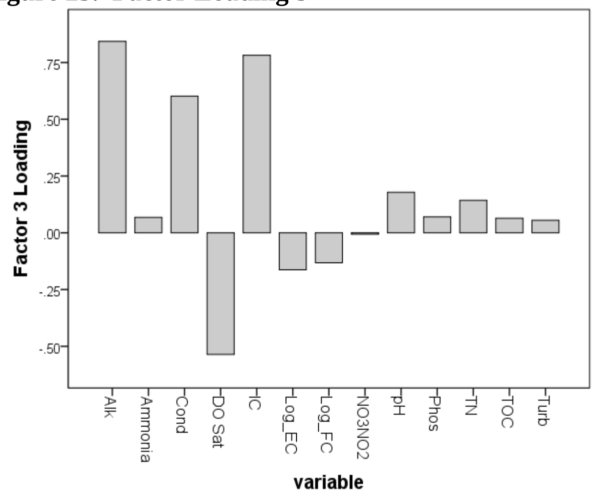


Figure 22. Factor Loading 2

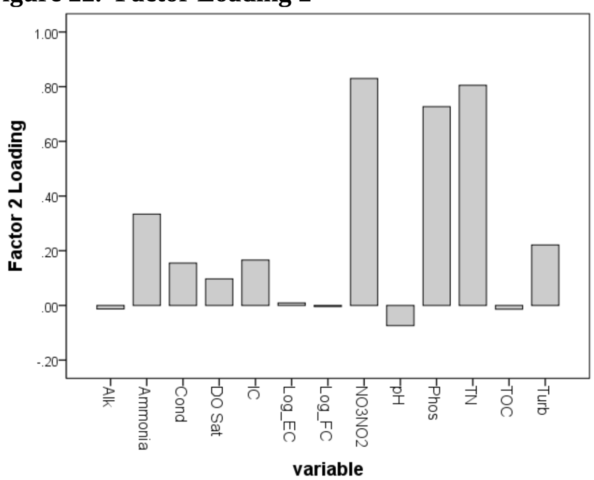
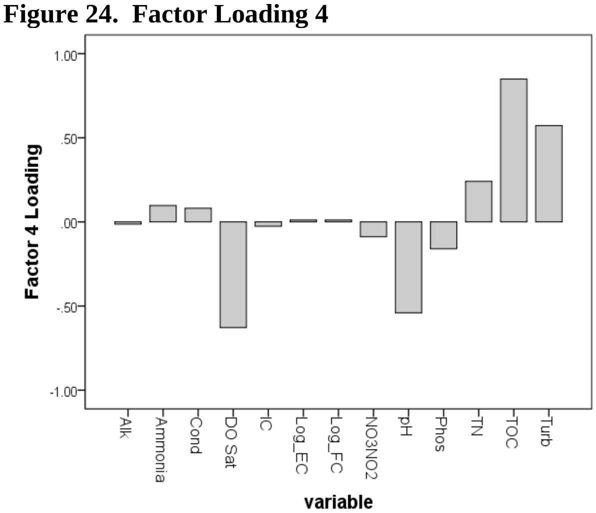


Figure 24. Factor Loading 4



5.0 DISCUSSION

Because salty water has higher conductance than fresh water, specific conductance was measured to determine the degree to which salty water was intruding tidally from Lake Pontchartrain. Specific conductance (measured in microSiemens per centimeter- µS-cm-1) analyses indicated that BFAB6 (outlier points) and BFAB10 appeared to be tidally influenced by Lake Pontchartrain (Figure 12). In general, specific conductance was slightly higher in the Abita River watershed, the lower and more tidally influenced portion of the study area (Figure 12).

BFAB9 had significantly greater fecal coliform concentration than any other sample sites except for BFAB5 (Figure 16, Kruskal-Wallis analysis shown in Appendix A). More than 25 percent of the samples taken at BFAB9 were above the Louisiana state standard for a single sample (400 MPN/100mL water), Figure 16. It is also important to mention that BFAB9 is sited within an urban area, the Town of Abita Springs, but is not tidally influenced by Lake Pontchartrain, as BFAB6 and BFAB10 are. BFAB9 showed an increase in fecal coliform and was significantly greater than fecal counts for BFAB7 (upstream of BFAB9) (Kruskal Wallis, p-value = 0.0257, full results shown in Appendix A).

BFAB5 had greater fecal coliform concentration (though not significantly) than all other sites with the exception of site BFAB9. Seventy-five percent of the samples for BFAB5 were slightly under the state standard. BFAB6 (the downstream-most site on the Bogue Falaya River) met the state standard for fecal coliform (Figure 16), but again this site is tidally influenced, as is BFAB10. The location of site BFAB5 is nearest the urban area of the City of Covington, but is not tidally influenced by Lake Pontchartrain. Sites upstream of urban areas showed similar low fecal coliform levels. Figure 3 shows that sites BFAB 1-3 are upstream of urban areas (the City of Covington and the Town of Abita Springs) and all had similar low fecal coliform counts (Figure 16).

Between the two rivers, the Abita had lower dissolved oxygen, and higher turbidity, total organic carbon, and ammonia-ammonium-nitrogen concentrations in the entire system, and increasing levels of alkalinity and total inorganic carbon as the river flowed downstream. The Abita River is much smaller than the Bogue Falaya with a discharge of around 5,000 cubic feet per second (cfs) as opposed to Bogue Falaya's 9,000-20,000 cfs. So, the water quality would be impacted more by land use and groundwater. The Abita is also fed by natural springs; which could account for some of the systemic water quality differences. Most if not all businesses and homes utilize groundwater as the primary potable water source. This water is higher in alkalinity and could explain the rise in alkalinity (and the corresponding total inorganic carbon- a constituent of alkalinity) in the downstream direction (as the population becomes denser).

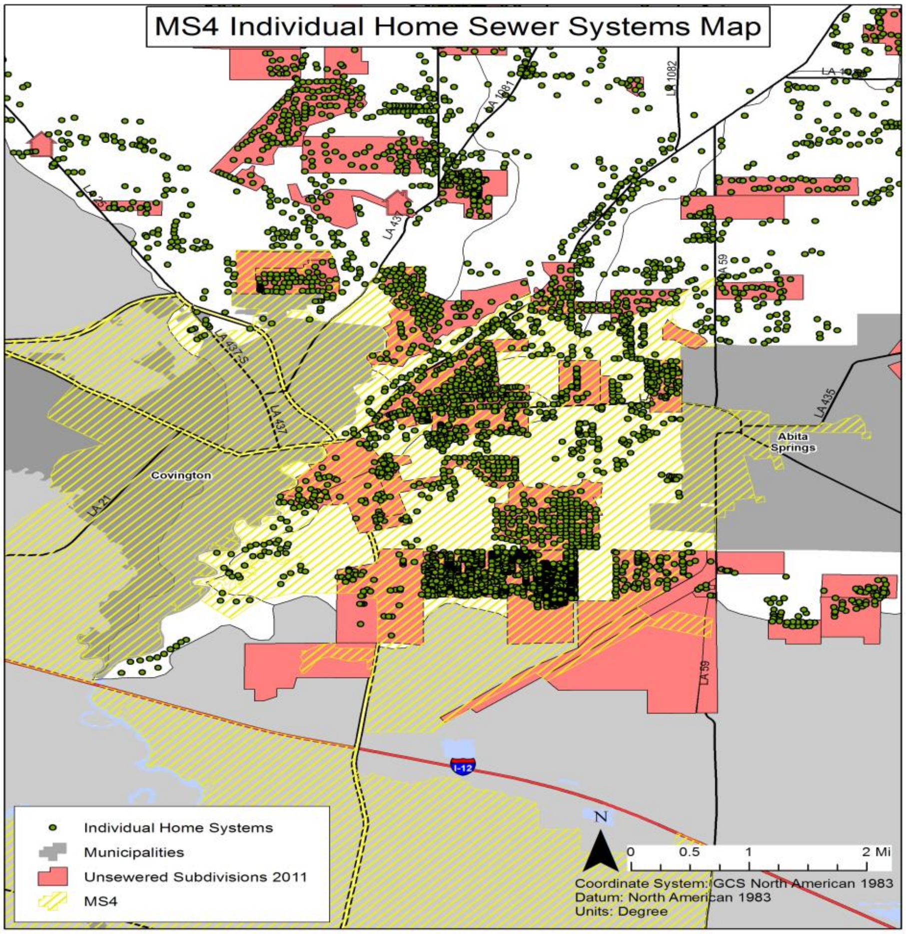
The most striking trend seen in the nutrients was the spike observed in nitrogen and phosphorus species between Sites BFAB9 and BFAB10 (Figures 13-15). As mentioned in the results, these spikes indicate that a source must exist between these two sites. Land use and a survey of LPDES-permitted facilities led LPBF to believe the source was either discharges from two large wastewater treatment plants entering the river at this point or discharges from many individually-sewered homes in this area (Figure 25).

LPBF conducted extra source-tracking sampling in December 2010 to try to locate the sources. The lab utilized for analysis, SLU Microbiology Lab, donated analyses of additional surface water sites and wells for source tracking. Eleven sites in ditches and along the Abita River (Figure 26) were sampled for ammonia-ammonium-nitrogen, nitrate-nitrite-nitrogen, phosphate-phosphorus, and alkalinity. These sites were sampled as the surrounding neighborhood is densely populated yet the majority of homes are on individual wastewater systems (Figure 25). While some spikes were observed (yellow and orange boxes in Figure 27), no clear pattern emerged.

There are also three (that consolidated into two) regional/municipal wastewater treatment plants that discharge into the Abita at this point. The Arrowwood regional wastewater treatment plant was permitted to assume treatment of St. Tammany Parish's Sewer District (SD) 6's waste as of July 2010 and final termination of the SD6 permit occurred in January 2011. The SD6 plant had a discharge of 0.3 mgd (million gallons per day). It had been poorly functioning and could account for the nitrate-nitrite-nitrogen spikes (Figure 18) seen early in the study. The Arrowwood facility is a well-functioning facility that had a design capacity of 1.6 mgd which increased to 2.0 mgd after the inclusion of SD6 and local subdivisions. While the Arrowwood plant is well functioning, it does not have nitrate/nitrite or phosphate effluent limits (no plants in LA currently do). The treatment process converts ammonia to nitrates/nitrites (nitrification) and phosphates are a product in waste that is not removed. LDEQ is currently studying potential in-stream limits for these nutrients; which could result in future discharge monitoring/ effluent limits and/or TMDLs.

The other plant currently discharging into the Abita River is the Town of Abita Springs; which has a design capacity of 0.4 mgd. However, this plant is not functionally optimally. It had a recent compliance order in July 2011, covering exceedances in fecal coliform, chemical biological oxygen demand (CBOD), Ammonia, and total suspended solids (TSS) from 2004 through 2010. While the discharge is far less than the Arrowwood plant, this poorly functioning plant could also account for some of the high nutrient levels observed.

Figure 25. Homes on Individual Wastewater Treatment in lower Bogue Falaya and Abita Watersheds



(from- http://etd.lsu.edu/docs/available/etd-04132012-200451/unrestricted/corethesis.pdf.pdf)

Figure 26. Sample Sites for Extra Nutrient Source-Tracking Water Monitoring

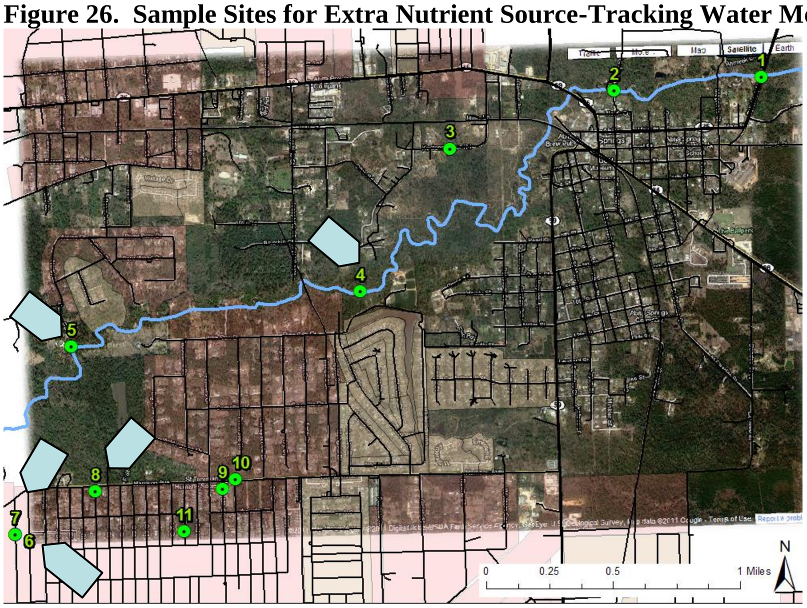


Figure 27. Data from Extra Sampling (Note- site numbers below match numbers shown in Figure 26).

Recon on Abita River, 12-20-10

Site	Location	date	NH4	NO3_NO2	PO4	Alkalinity
AR1	Abita River @ Hwy 435	12/20/2010	0.6611	0.6012	0.0670	22.264
AR2	Abita River @ Hickory	12/20/2010	0.5947	0.0979	-0.0036	55.154
AR3	Creek on Kustenmacher Rd	12/20/2010	1.9219	0.2061	0.8359	56.166
AR4	Abita @ Kustenmacher Rd (Arrowood)	12/20/2010	0.3599	5.1489	1.8910	160.402
AR5	Abita @ Ellis Rd.	12/20/2010	0.3293	4.6060	1.4883	472.604
AR6	Ditch @ K West St.	12/20/2010	9.6735	2.6341	1.8192	189.244
AR7	Well @ K West St.	12/20/2010	77.7953	3.1899	5.0079	109.296
AR8	Ditch @ G St. and Harrison	12/20/2010	19.3214	5.8645	2.8378	95.634
AR9	Well @ Humane Society on Harrison	12/20/2010	0.3420	0.0568	0.2107	117.898
AR10	Ditch @ 5th St. and Harrison	12/20/2010	0.0715	0.0728	0.2001	22.264
AR11	Well @ 2nd Ave.	12/20/2010	0.2323	0.0644	0.1023	128.018

Notes:
AR4- High NO2-NO3, High Alkalinity
AR5- High NO2-NO3, Very High Alkalinity
AR6- High Alkalinity
AR7- Very High NH4 and PO4
AR8- High NH4, NO-NO3, and PO4

Data Quality Analysis and Equipment Calibration: All *in situ* field data were collected in triplicate. The triplicate data was subjected to precision analysis. Precision is expressed as the relative percent difference (RPD). Microsoft Excel was used for these calculations. All RPD analyses yielded acceptable results.

$$RPD = (X^1 - X^2) / X(100)$$

Where X^1 and X^2 are maximum and minimum sample values from daily triplicate samples

Relative percent difference data:

	RPD	Total	Acceptable	% Acceptable
Temperature	>5%	472	472	100.0%
Dissolved Oxygen	>10%	470	469	99.8%
Specific Conductance	>5%	467	466	99.8%

All field equipment was regularly calibrated according to the manufacturer's instructions:

BFAB Calibration Log

Date	Instrument	Procedure
11/08/10	YSI 85	Changed DO tip
02/28/11	YSI 85	Changed DO tip
03/14/11	Turbidimeter	Test W/ Standards
03/14/11	ysi 60	Ph Solution Changed
03/14/11	YSI 85	Changed DO tip
03/21/11	Turbidimeter	Test W/ Standards
03/21/11	YSI 85	Changed DO tip
05/11/11	Turbidimeter	Test W/ Standards

05/11/11	ysi 60	Ph Solution Changed
05/11/11	YSI 85	Changed DO tip
07/18/11	Turbidimeter	Test W/ Standards
07/18/11	YSI 85	Changed DO tip
09/12/11	Turbidimeter	Test W/ Standards
09/12/11	ysi 60	Ph Solution Changed
09/12/11	YSI 85	Changed DO tip
11/21/11	Turbidimeter	Test W/ Standards
11/21/11	ysi 60	Ph Solution Changed
11/21/11	YSI 85	Changed DO tip
02/13/12	Turbidimeter	Test W/ Standards
02/13/12	YSI 85	Changed DO tip
03/26/12	Turbidimeter	Test W/ Standards
03/26/12	YSI 85	Changed DO tip
05/07/12	Turbidimeter	Test W/ Standards
05/07/12	ysi 60	Ph Solution Changed
05/07/12	YSI 85	Changed DO tip
05/21/12	ysi 60	Ph Solution Changed
06/18/12	ysi 60	Ph Solution Changed

Data Sharing/ Education and Outreach:

- Data collected through this research was used in the completion of a Master's Thesis at LSU entitled "Spatial Assessment and Analysis of Pollution Sources and Water Quality in the Bogus Falaya River and Abita River Watersheds, St. Tammany Parish, LA". The research focused on correlations between water quality parameters and land use/ wastewater sources GIS data (Core, 2012).
- Some of the techniques utilized and data collected for the above thesis was submitted as an abstract for the Louisiana Water Environment Association conference. The abstract was accepted and the paper was presented at the conference in New Orleans, May 21-22, 2012. (abstract attached as Appendix C).
- Water quality data was regularly (semi-annually) graphed and shared with the St. Tammany Water Quality Task Force.
- All data collected in the study (the finalized database) has been shared with LDEQ.
- All data collected in the study (the finalized database) has been shared with St. Tammany Parish.

6.0 CONCLUSION

Two years of water quality monitoring in the Bogue Falaya and Abita Watersheds was completed as part of the Bogue Falaya and Abita Watershed Implementation Plan. The water quality monitoring indicated anomalously high nutrient values in the lower Abita River (Site BFAB10) and led LPBF to investigate potential sources. The potential sources include two regional wastewater treatment plants and numerous homes on individual systems occurring in the area.

For fecal coliform bacteria, the greatest levels were seen at slightly upstream sites (Sites BFAB5 and 9) as the lowest sites (Sites BFAB6 and 10) are tidally influenced by Lake Pontchartrain. The fecal coliform levels appeared to be rising throughout the course of the study and indicate that pollution sources exist (detailed in Core 2012 thesis). St. Tammany Parish is working on regionalizing its wastewater system, but these rivers will have to be monitored to ensure that the fecal levels do not rise into the future.

The Bogue Falaya and Abita Watershed Implementation Plan (Bourgeois-Calvin and Core, 2012) incorporated water quality data, GIS, modeling (St. Tammany Parish, 2007), TMDL results, and stakeholder knowledge to assess pollution sources and their contributing loads and recommend targeted areas for project implementation to clean waterways. This water quality monitoring revealed sites in the downstream region of the Abita River to have abnormally high parameters- mirroring the findings of the WIP and providing a baseline of data from which to show improvements in water quality. The WIP now moves into the implementation phase where the stakeholders are applying for funding to implement the "Best First Projects".

Stakeholders in the WIP process identified six management measures to help bring fecal and dissolved oxygen levels in line:

1. Addressing Small Wastewater Package Plants
2. Construction Stormwater Best Management Practices (Programs, Education, Support, Incentives)
3. Home System Inspections/ Assistance/ Education
4. Horse Program (Equine Water Quality Education Series)
5. I & I assessment (LRWA)
6. Stream Restoration

Continued water quality monitoring was recommended to document the improvements in water quality due to implementation of the management measures.

The goal is to show measurable water quality improvements within five years.

As St. Tammany Parish develops and grows in population, pollution from urban land use will continue to put pressure on the water quality of the Bogue Falaya River and Abita River watersheds. The Dissolved Oxygen-Demanding Substances TMDL recently completed in the Lower-Tchefuncte River (and by extension, the Bogue Falaya Watershed) will be an important tool for water quality improvement in the Bogue Falaya, Abita, and Lower-Tchefuncte River watersheds.

> LDEQ recommends that the primary solutions to the water quality problems for Subsegments 040802 and 040803 include the large-scale regionalization of sewage treatment and the rehabilitation and upgrade of existing problematic (leaks, overflows, improperly sized pipes, etc.) sewage collection and/or treatment systems (LDEQ 2011: xliii).

Reductions in pollution loads provided by TMDLs will be enforceable and must be met by the municipalities. The Lower-Tchefuncte River TMDLs are similar to those of several urban watersheds in south Louisiana. All show similar issues of high numbers and densities of individual home systems and poorly functioning commercial Wastewater Treatment Plants (WWTP), leading to low dissolved oxygen and/or high fecal coliform levels. Regionalization is imperative management strategy for the improvement of water quality in watersheds throughout the Pontchartrain Basin and south Louisiana. St. Tammany Parish is being proactive and has developed plans to regionalize a large portion of the southern end of the parish. Future research needs to include continued water quality monitoring of the Bogue Falaya River and Abita River watersheds as St. Tammany Parish moves forward in the regionalization of its wastewater to satisfy the TMDLs.

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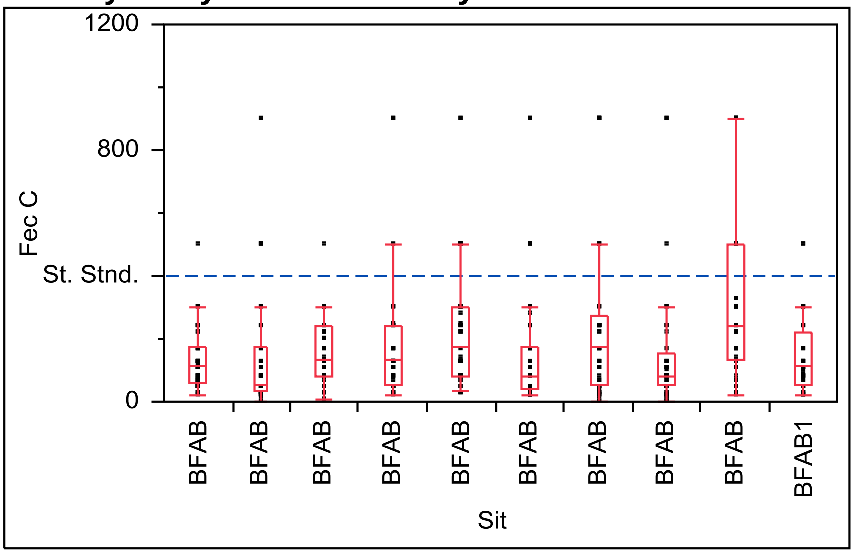
APPENDIX A: DATA ANALYSIS

<u>Fecal Coliform Wilcoxon / Kruskal-Wallis Tests (Rank Sums) Analysis</u>

Oneway Analysis of Fec Col By Site



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
BFAB1	49	10732.0	11809.0	219.020	-1.171
BFAB2	41	7133.00	9881.00	173.976	-3.238
BFAB3	49	12583.5	11809.0	256.806	0.842
BFAB4	49	12134.0	11809.0	247.633	0.353
BFAB5	49	14456.0	11809.0	295.020	2.879
BFAB6	49	9814.50	11809.0	200.296	-2.169
BFAB7	49	12546.5	11809.0	256.051	0.802
BFAB8	49	9622.00	11809.0	196.367	-2.379
BFAB9	49	16069.0	11809.0	327.939	4.634
BFAB10	48	10830.5	11568.0	225.635	-0.809

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
48.7970	9	<.0001*

Nonparametric Comparisons For Each Pair Using Wilcoxon Method

q*	Alpha
1.95996	0.05

Level	- Level	Score Mean Diff	Std Err Dif	Z	p-Value	Hodges-Lehmann	Lower CL	Upper CL
BFAB9	BFAB1	24.9184	5.727746	4.35047	<.0001*	140.000	80.000	210.000
BFAB9	BFAB2	24.5943	5.512478	4.46157	<.0001*	170.000	90.000	238.000
BFAB9	BFAB6	24.1837	5.726497	4.22312	<.0001*	147.000	70.000	220.000
BFAB9	BFAB8	23.9388	5.727837	4.17937	<.0001*	160.000	80.000	220.000
BFAB5	BFAB2	20.9209	5.507248	3.79879	0.0001*	80.000	50.000	150.000
BFAB5	BFAB1	18.2653	5.719272	3.19364	0.0014*	60.000	20.000	120.000
BFAB9	BFAB3	17.9388	5.725266	3.13327	0.0017*	110.000	40.000	190.000
BFAB9	BFAB4	17.6939	5.724935	3.09067	0.0020*	110.000	40.000	190.000
BFAB3	BFAB2	15.6122	5.506859	2.83505	0.0046*	55.000	20.000	100.000
BFAB4	BFAB2	14.5371	5.501716	2.64228	0.0082*	48.000	7.000	90.000

Level	- Level	Score Mean Diff	Std Err Dif	Z	p-Value	Hodges-Lehmann	Lower CL	Upper CL
BFAB7	BFAB2	12.9915	5.512775	2.35662	0.0184*	60.000	0.000	140.000
BFAB9	BFAB7	12.7755	5.727195	2.23068	0.0257*	70.000	0.000	170.000
BFAB10	BFAB2	11.1476	5.470131	2.03791	0.0416*	30.000	0.000	60.000
BFAB5	BFAB4	10.5510	5.714562	1.84634	0.0648	47.000	0.000	90.000
BFAB7	BFAB6	9.8980	5.725872	1.72864	0.0839	47.000	0.000	120.000
BFAB3	BFAB1	9.4286	5.715574	1.64963	0.0990	27.000	0.000	60.000
BFAB5	BFAB3	9.0816	5.709682	1.59057	0.1117	30.000	0.000	90.000
BFAB9	BFAB5	9.0816	5.721093	1.58739	0.1124	60.000	0.000	160.000
BFAB7	BFAB1	7.7143	5.725854	1.34727	0.1779	40.000	-10.000	110.000
BFAB10	BFAB8	7.2997	5.687223	1.28353	0.1993	20.000	-7.000	50.000
BFAB6	BFAB2	6.3390	5.498924	1.15277	0.2490	15.000	-7.000	50.000
BFAB10	BFAB6	6.0625	5.686713	1.06608	0.2864	15.000	-10.000	50.000
BFAB4	BFAB1	5.9796	5.711726	1.04690	0.2951	10.000	-20.000	60.000
BFAB8	BFAB2	5.5102	5.500686	1.00173	0.3165	20.000	-10.000	48.000
BFAB7	BFAB4	2.0000	5.721902	0.34953	0.7267	0.000	-28.000	80.000
BFAB7	BFAB3	1.5306	5.725284	0.26734	0.7892	0.000	-48.000	80.000
BFAB10	BFAB1	0.5774	5.689696	0.10148	0.9192	0.000	-30.000	30.000
BFAB8	BFAB6	-0.9592	5.708871	-0.16802	0.8666	0.000	-30.000	27.000
BFAB4	BFAB3	-2.1633	5.709589	-0.37888	0.7048	0.000	-50.000	30.000
BFAB10	BFAB4	-5.0315	5.687940	-0.88458	0.3764	-15.000	-50.000	20.000
BFAB10	BFAB7	-5.7532	5.699937	-1.00934	0.3128	-27.000	-110.000	20.000
BFAB6	BFAB1	-5.7551	5.716145	-1.00682	0.3140	-20.000	-47.000	10.000
BFAB7	BFAB5	-6.2653	5.727415	-1.09392	0.2740	-28.000	-80.000	30.000
BFAB8	BFAB1	-6.8776	5.714175	-1.20359	0.2287	-20.000	-48.000	10.000
BFAB10	BFAB3	-7.8771	5.688714	-1.38469	0.1661	-20.000	-60.000	0.000
BFAB8	BFAB7	-10.3673	5.727709	-1.81003	0.0703	-48.000	-120.000	0.000
BFAB6	BFAB4	-10.4286	5.714010	-1.82509	0.0680	-27.000	-70.000	0.000
BFAB8	BFAB4	-11.0204	5.712150	-1.92929	0.0537	-30.000	-72.000	0.000
BFAB2	BFAB1	-11.3564	5.506037	-2.06254	0.0392*	-30.000	-57.000	0.000
BFAB6	BFAB3	-12.6122	5.721148	-2.20450	0.0275*	-47.000	-80.000	0.000
BFAB8	BFAB3	-13.8776	5.718665	-2.42671	0.0152*	-50.000	-80.000	0.000
BFAB10	BFAB5	-14.8676	5.689300	-2.61325	0.0090*	-50.000	-110.000	-7.000
BFAB6	BFAB5	-19.1633	5.721994	-3.34905	0.0008*	-63.000	-130.000	-30.000
BFAB8	BFAB5	-19.8776	5.718390	-3.47608	0.0005*	-78.000	-137.000	-30.000
BFAB10	BFAB9	-20.9713	5.698938	-3.67986	0.0002*	-140.000	-200.000	-60.000

APPENDIX B: Description of Parameters Analyzed

Parameter	Method	Equipment
Dissolved Oxygen	Standard Methods for Examination of Water and Wastewater, 20^{th} Ed. method 4500-OG	YSI85 S-C-DO-T Meter 0-20mg/L range, ± 0.3mg/L accuracy
Temperature	Standard Methods for Examination of Water and Wastewater, 20^{th} Ed. method 2550B	YSI85 S-C-DO-T Meter -5 to +65°C range, 0.1°C accuracy
Specific Conductance	Standard Methods for Examination of Water and Wastewater, 20^{th} Ed. method 2510B	YSI85 S-C-DO-T Meter 0 to 4999 µS/cm range, ± 0.5% accuracy
Turbidity	Standard Methods for Examination of Water and Wastewater, 20^{th} Ed. method 2130 B	Hach Portable Turbidimeter 0 to 1000 NTU range, 0.01 NTU accuracy
pH	Standard Methods for Examination of Water and Wastewater, 20^{th} Ed. method 4500-H^+B	YSI 60 pH Meter 0 to 14.00 range, 0.1pH accuracy
Alkalinity	Standard Methods for Examination of Water and Wastewater, 21st ed. Method 2320B, Titration method	Oakton pH 510 series meter Brinkman digital buret both 0-20mg/L range and >20 mg/L method used, depending on sample As per Standard method, no general precision statement can be made.
Nitrate/Nitrite	Standard Methods for Examination of Water and Wastewater, 21st ed. SM 4500-NO3 F	Hach DR5000 Spectrophotometer BioTek PowerWave HT Microplate Spectrophotometer 0.1-unlimted range (dilution scheme used for high range samples)
Orthophosphate as P	Standard Methods for Examination of Water and Wastewater, 21st ed. SM 4500-P E	Hach DR5000 Spectrophotometer BioTek PowerWave HT Microplate Spectrophotometer 0.01-unlimted range (dilution scheme used for high range samples) precision: for 0.228 ug/L sample Relative SD =3.03
TOC/IC	Standard Methods for Examination of Water and Wastewater, 20th ed. SM 5310 B	Shimadzu TOC-Vcpn Range: 0.1-unlimited range (dilution scheme for high range samples) precision: 5-10% depending on sample characteristics
TN	High Temperature Combustion/Chemilumenscence	Shimadzu TOC-Vcpn, TNM-1 module 0.1-200mg/L

		precision: CV 3% max
Ammonia as N	Standard Methods for Examination of Water and Wastewater, 20th ed. SM 4500-NH3 G B	Hach DR5000 Spectrophotometer BioTek PowerWave HT Microplate Spectrophotometer 0.05-unlimited range (dilution scheme used for high range samples)
Fecal coliform	Standard Methods for Examination of Water and Wastewater, 20th ed. SM 9221-E (A1)	detection limit: MPN 2/100ml precision: follows MPN chart in Standard Methods
Escherichia coli	Standard Methods for Examination of Water and Wastewater, 20th ed. SM 9225-C	detection limit: MPN 2/100ml precision: follows MPN chart in Standard Methods

Alkalinity (Total Alkalinity units: mg/L Ca CO_3)

Alkalinity is a measure of the capacity of water to neutralize acids. Alkaline compounds in the water such as bicarbonates, carbonates, and hydroxides remove H+ ions and lower the acidity of the water (which means increased pH). They usually do this by combining with the H+ ions to make new compounds. Without this acid-neutralizing capacity, any acid added to a stream would cause an immediate change in the pH. Measuring alkalinity is important in determining a stream's ability to neutralize acidic pollution from rainfall or wastewater. It's one of the best measures of the sensitivity of the stream to acid inputs. Alkalinity in streams is influenced by rocks and soils, salts, certain plant activities, and certain industrial wastewater discharges.
Total alkalinity is measured by measuring the amount of acid (e.g., sulfuric acid) needed to bring the sample to a pH of 4.2. At this pH all the alkaline compounds in the sample are "used up." The result is reported as milligrams per liter of calcium carbonate (mg/L $CaCO_3$).

Ammonia Nitrogen (NH_4^+ + NH_3 mg/L N)

Ammonia (NH_3) is a common toxicant derived from wastes, fertilizers, and natural processes. Ammonia nitrogen includes both the ionized form (ammonium, NH_4^+) and the unionized form (ammonia, NH_3). An increase in pH favors formation of the more toxic unionized form (NH_3), while a decrease favors the ionized (NH_4^+) form. Temperature also affects the toxicity of ammonia to aquatic life. Ammonia is a common cause of fish kills, but the most common problems associated with ammonia relate to elevated concentrations affecting fish growth, gill condition, organ weights, and hematocrit (Milne et al. 2000). Exposure duration and frequency strongly influence the severity of effects (Milne et al. 2000).

Ammonia in sediments typically results from bacterial decomposition of natural and anthropogenic organic matter that accumulates in sediment. Sediment microbiota mineralize organic nitrogen or (less commonly) produce ammonia by dissimilatory nitrate reduction. Ammonia is especially prevalent in anoxic sediments because nitrification (the oxidation of ammonia to nitrite [NO_2^-] and nitrate [NO_3^-]) is inhibited. Ammonia generated in sediment may be toxic to benthic or surface water biota (Lapota et al. 2000).

Ammonia also exerts a biochemical oxygen demand on receiving waters (referred to as nitrogenous biological oxygen demand or NBOD) because dissolved oxygen is consumed as bacteria and other microbes oxidize ammonia into nitrite and nitrate. The resulting dissolved oxygen reductions can decrease species diversity and even cause fish kills. Additionally, ammonia can lead to heavy plant growth (eutrophication) due to its nutrient. Conversely, algae and macrophytes take up ammonia, thereby reducing aqueous concentrations.

Conductivity (µs/cm)

Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Organic compounds like oil, phenol, alcohol, and sugar do not conduct electrical current very well and therefore have a low conductivity when in water. Conductivity is also affected by temperature: the warmer the water, the higher the conductivity. For this reason, conductivity is reported as conductivity at 25 degrees Celsius (25 C).

Conductivity in streams and rivers is affected primarily by the geology of the area through which the water flows. Streams that run through areas with granite bedrock tend to have lower conductivity because granite is composed of more inert materials that do not ionize (dissolve into ionic components) when washed into the water. On the other hand, streams that run through areas with clay soils tend to have higher conductivity because of the presence of materials that ionize when washed into the water. Ground water inflows can have the same effects depending on the bedrock they flow through.

Discharges to streams can change the conductivity depending on their make-up. A failing sewage system would raise the conductivity because of the presence of chloride, phosphate, nitrate, and other ions.

The basic unit of measurement of conductivity is the mho or siemens. Conductivity is measured in micromhos per centimeter (µmhos/cm) or microsiemens per centimeter (µs/cm). Distilled water has a conductivity in the range of 0.5 to 3 µmhos/cm. The conductivity of rivers in the United States generally ranges from 50 to 1500 µmhos/cm. Studies of inland fresh waters indicate that streams supporting good mixed fisheries have a range between 150 and 500 µmhos/cm. Conductivity outside this range could indicate that the water is not suitable for certain species of fish or macroinvertebrates. Industrial waters can range as high as 10,000 µmhos/cm.

Dissolved Oxygen (DO mg/L)

The stream system both produces and consumes oxygen. It gains oxygen from the atmosphere and from plants as a result of photosynthesis. Running water, because of its churning, dissolves more oxygen than still water, such as that in a reservoir behind a dam. Respiration by aquatic animals, decomposition, and various chemical reactions consume oxygen.

Wastewater from sewage treatment plants often contains organic materials that are decomposed by microorganisms, which use oxygen in the process. Other sources of oxygen-consuming waste include stormwater runoff from farmland or urban streets, feedlots, and failing septic systems.

Oxygen is measured in its dissolved form as dissolved oxygen (DO). If more oxygen is consumed than is produced, dissolved oxygen levels decline and some sensitive animals may move away, weaken, or die.

DO levels fluctuate seasonally and over a 24-hour period. They vary with water temperature and altitude. Cold water holds more oxygen than warm water and water holds less oxygen at higher altitudes. Thermal discharges, such as water used to cool machinery in a manufacturing plant or a power plant, raise the temperature of water and lower its oxygen content. Aquatic animals are most vulnerable to lowered DO levels in the early morning on hot summer days when stream flows are low, water temperatures are high, and aquatic plants have not been producing oxygen since sunset.

Total Organic Carbon and Inorganic Carbon (TOC/IC mg/L C)

Total organic carbon (TOC) is the sum of all organic carbon and is expressed in mg/L C. Total organic carbon comes from surface water runoff, plant decomposition, bacterial growth and decay, and waste water intrusion. Although TOC itself is not an indicator of biochemical oxygen demand (BOD), it is useful in determining carbon inputs to the system, and which streams have the potential for increased oxygen consumption.

Nitrate + Nitrite (NO_3^- + NO_2^- mg/L N)

Nitrate and Nitrite are a form of nitrogen, which is found in several different forms in terrestrial and aquatic ecosystems. Nitrates are essential plant nutrients, but in excess amounts they can cause significant water quality problems. Together with phosphorus, nitrates in excess amounts can accelerate eutrophication, causing dramatic increases in aquatic plant growth and changes in the types of plants and animals that live in the stream. This, in turn, affects dissolved oxygen, temperature, and other indicators. Excess nitrates can cause hypoxia (low levels of dissolved oxygen) and can become toxic to warm-blooded animals at higher concentrations (10 mg/L) or higher) under certain conditions. The natural level of nitrate in surface water is typically low (less than 1 mg/L); in the effluent of wastewater treatment plants, it can range up to 30 mg/L. Sources of nitrates include wastewater treatment plants, runoff from fertilized lawns and cropland, failing on-site septic systems, runoff from animal manure storage areas, and industrial discharges that contain corrosion inhibitors.

Ortho Phosphate (PO4 mg/L P)

Both phosphorus and nitrogen are essential nutrients for the plants and animals that make up the aquatic food web. Since phosphorus is the nutrient in short supply in most fresh waters, even a modest increase in phosphorus can, under the right conditions, set off a whole chain of undesirable events in a stream including accelerated plant growth, algae blooms, low dissolved oxygen, and the death of certain fish, invertebrates, and other aquatic animals.

There are many sources of phosphorus, both natural and human. These include soil and rocks, wastewater treatment plants, runoff from fertilized lawns and cropland, failing septic systems, runoff from animal manure storage areas, disturbed land areas, drained wetlands, water treatment, and commercial cleaning preparations.

APPENDIX C: Abstract for LWEA

SPATIAL ASSESMENT AND ANALYSIS OF POLLUTION SOURCES AND WATER QUALITY IN THE BOGUE FALAYA RIVER AND ABITA RIVER WATERSHEDS, ST. TAMMANY PARISH, LA

By: Chelsea Core

ABSTRACT

Watershed planning is used to characterize the environment and locate pollution sources, enabling communities to address pollution in and ensure the health and vitality of waterways. The Lake Pontchartrain Basin Foundation (LPBF) partnered with the Louisiana Department of Environmental Quality (LDEQ) to write a Watershed Implementation Plan (WIP) for Bogue Falaya and Abita River watersheds in St Tammany Parish, LA. This research provides a process to spatially track pollution entering waterways by characterizing the watersheds and identifying pollution sources. Geographic Information Systems (GIS) was utilized to display spatial information to locate potential pollution sources within each watershed. LPBF collected the needed data and information and assembled it into a geodatabase. Data layers were mapped to identify and quantify potential pollution sources. Water quality monitoring data, collected by the LPBF, was also mapped and analyzed to identify correlations between water quality parameters (fecal coliform, turbidity, and specific conductance) and pollution source locations and densities.

LPBF identified municipalities, transportation corridors, waterbodies, and watershed boundaries. The Bogue Falaya and Abita River watersheds were further delineated into six subwatersheds (English Branch, Lower Bogue Falaya, Abita, Little Bogue Falaya, Simalusa Creek, and Upper Bogue Falaya River). Land use percentages were calculated with ArcMap. Potential pollution sources mapped included commercial wastewater treatment plants (WWTPs), subdivisions with and without community WWTPs, and home treatment systems for each subwatershed. Non-parametric statistics used were Spearman's rank correlation coefficient and Kruskal–Wallis one-way analysis of variance. LPBF produced a Kernel density layer using the ArcMap Spatial Analysis extension tool for commercial WWTPs and individual home systems.

Overall land use for the watersheds indicated a high percentage of forest land followed by agricultural land. Land use percentages were also broken down by each sub-watershed, showing the highest urban percentages in the Lower Bogue Falaya and Abita River. LPBF quantified the numbers of subdivisions without community wastewater treatment, commercial WWTPs, and individual home treatment systems in each of the six sub-watersheds. This showed that the greatest numbers of sources were also located in the Lower Bogue Falaya and Abita River subwatersheds. Water quality analysis showed greater fecal coliform counts at sample sites near urban areas and also showed significant and positive correlations between turbidity and fecal coliform, indicating the influence of stormwater. Kernel density analysis indicated greater density of commercial WWTPs along roadway corridors and between municipalities in the southern portion of the watersheds. High fecal coliform counts and the greatest density of pollution sources occurred in the most urban areas of the watersheds (the Lower Bogue Falaya and the Abita River sub-watersheds).

Given the correlation between fecal coliform and home and commercial WWTP density in the urban areas, regionalization of the wastewater infrastructure provides the best method to reduce numerous pollution sources. Using a combination of GIS and water quality analysis, the location and density of pollution sources could be found and compared to the water condition t compose a complete picture and suggest future steps. Such analysis would be useful in other urban watershed-based planning efforts.